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(54) **DC polarization device for high power, low intermodulation RF-systems**

(57) The invention concerns DC-polarization devices for radio-frequency transmission systems of high power and low intermodulation, comprising a station (A) originating the RF signal, a station (B) receiving said RF signal from A, and a source D of direct current DC to be fed to B, and connected in a knot N to the line AB, the branches AN and DN comprising a short circuit stub (STU2) respectively an open circuit stub (STU1).

Typically the normalised impedance ( $Z'_{op}$ ) of stub (STU2) is substantially equal to the normalise admittance ( $Y_{os}$ ) of stub (STU1), and the distance of the free heads of the near ends of the two stubs is the lowest possible.

Fig.8

## Description

This invention concerns a DC polarization device for radio frequency transmission systems of high power and low intermodulation, comprising resonator circuits made up of stubs.

The invention refers specifically to a so called BIAS-T system comprising a radio frequency (RF) transmitting station or source and a receiving station for the afore-mentioned RF but which must be activated by DC power coming from an outside source and injected on the line between the two stations.

A polarizator is therefore a circuit having the purpose of introducing the DC power (from an outside source) in a part of the RF circuit without altering its function. Just for clarification, the working principle of a conventional DC polarizator is illustrated in simple form in fig. 1 in which AB indicates a radio frequency circuit, consisting, for example, of the RF signal station B in which the DC bias comes from the power source in D.

To this end, an S block must ideally be a short circuit in series for the RF signal and an open circuit series for the DC, plus an open series for the RF. Fig. 2 shows emblematically the simplest embodiment of the scheme of fig. 1; a capacity C works as high-pass filter and an inductance L (in series with D) works as a low-pass filter whereby a DC signal introduced in D can reach B through the co-axial line 1 without involving A.

The fig. 2 circuit can be used at relatively low frequencies in the order of hundreds of MHz and for power below tens of Watt.

When, however, the frequency exceeds for example the GHz and the power runs to hundreds of Watt, the devices of the type shown in fig.2 or similar are unsuitable and do not satisfy the requirements, giving rise to various inconveniences, due to which more complex circuits are needed, comprising specific elements such as resonators, made for instance with stubs on the two branches AB of fig. 2.

For stub is generally intended a co-axial short or open circuit and accordingly the device shown in fig.2, which is the co-axial version, incorporates two stubs assuming a structure as witnessed with the equivalent schemes of figures 3 and 4.

In these figures, the RS1 resonator in series with A is made of an inductance L1 and a C1 capacity in series with the aforementioned L1, while the RS2 resonator is made of L2 and C2 connected in parallel. In fig.4 the RS1 and RS2 resonators reach the knot N positioned on the co-axial line 1 between A and B; the RS1 and RS2 resonators must keep the impedance matching on the AB line. Being a co-axial line, the resonators can take on the form of stubs with cavities C for example in the inner co-axial conductor, formed respectively of an external co-axial conductor of a branch (for instance A) in which cavity is inserted a protuberance of the inside co-axial conductor of the branch B.

Fig. 5 shows a classic schematic partial cross-section of a resonator, for example RS1 with a STU1 stub;

CE1 is the outer conductor of the co-axial line: 1 between A and B, the inner CI (A) co-axial conductor having a cylindrical cavity CC with an opening AP through which is inserted the PR1 protuberance of the inner conductor C1 (B) of the branch B of the co-axial 1 between A and B. The CC cavity is closed at its other extremity by the bottom 61.

The cavity CC in the internal conductor CI (A) and the protuberance PR1 of the inside conductor CI (B) together form a stub ST1 terminated in a open circuit (W-Z). In a narrow band, this stub ST1 (forming the RS1 resonator) can be equivalently represented by the circuit L1, C1 of fig. 3. Fig. 6 shows the other possible stub STU2 terminated with a short circuit for the RF and also formed by a cavity and a protuberance. The inner conductor CI2 (B) shows the protuberance PR2 (B) which is closed in a short circuit on the bottom X-X' of the cylindrical cavity CC connected to the outer conductor CE2 of the branch AB.

For the best functioning of the two stubs STU1 and STU2, taken singularly, it is recommended that: the STU1 stub in series on A-B (fig.5) must have a characteristic impedance which is the lowest possible, in order to have, among other things, the least of reflection.

If, however, the two stubs are used contemporarily, that is, combining the afore-mentioned stubs STU1 (series) and STU2 (parallel) with the features there immediately favorable specified above, among other drawbacks, the following disadvantages which are of extreme nuisance to an "obvious" combination occur;

- the two reflections not only are not eliminated but are even free to add to each other,
- even if there was a matching, the compensation which might result would always be only partial.

The object of the present invention is to provide a polarizator which doesn't have the the aforementioned impediments, has simple constructional design and is very reliable in use.

It has now been found that the drawbacks just mentioned are effectively eliminated with two critical contemporary measures consisting in:

1. Giving to the parallel stub STU2 a characteristic normalized impedance  $Z'_{op}$  equal to the characteristic normalized admittance of the series stub STU1, said admittance being the highest possible, compatibly with the realization possibilities;
2. Putting the near ends of the two stubs at the lowest possible distance in particular at a distance below at least  $\lambda/100$  (where  $\lambda$  corresponds to the central frequency FO of the RF signal) the maximum of such a distance being below  $\lambda/20$ .

In effect by not respecting the condition 1, for instance, by making, as is possible and immediate, the impedance of STU2 not corresponding to the maximum admittance of STU1 in particular by making the imped-

ance of STU1, (apparently more favorable) above the said optimal value, the reflections occur which can easily combine with each other and cause a decided worsening of the characteristics.

As to the measure 2 (minimum distance) with increasing values from the minimum indicated ( $\lambda/100$ ) one has first a reduction of the compensation followed by a rising increase in the total reflection, going up to the arithmetical sum of the two reflections for a distance of  $\lambda/4$  well outside the critical interval according to the invention.

Further features of the invention are evidenced in the sub claims.

The different aspects and advantages of the invention will be more clearly apparent from the description of the preferred embodiments illustrated in the fig.7 diagram which is a cross-section view of the polarization device according to the invention, and in the fig. 8, a simplified representation on an enlarged scale which facilitates the ready understanding of the said fig.7.

In the figures 7 and 8 with CE and CI are indicated again the outer and inner conductors of the RF coaxial line COAX between A and B. The DC feed is introduced through a passing condenser CP put between the source D and the earth MA.

The other end E of condenser CP is connected with the inner conductor EF (20) of coaxial stub STU2 provided inside an upturned glass GHG'H' the outer cover ME of which acts as the inner conductor in the low impedance coaxial line and the outer conductor KLK'L' of which extends till to meet in MM' the outer conductor of coaxial COX in which the radio-frequency RF signals travels.

The bottom of glass GHG'H' is welded in P to a conductor PC soldered, on its turn, in C to the inner conductor CI of said coaxial in which the polarization DC current is to be injected.

Typically the inner conductor CI of the RF line between A and B is now divided in two parts AC' e CB isolated from each other. The part AC' contains a cylindrical axial bore 18(forming cavity CC') which acts as outer conductor of the low impedance open circuit stub STU1 the internal conductor of which is the continuation towards the left hand of the CB half namely is the protuberance PR1 of the inner conductor CI' (B) of branch B.

In the simplified scheme of figure 8 are clearly evidenced the particular features that:

- in the first cylindrical cavity CC' (18) inside the inner conductor CI (A) of the branch A coaxial line extends the protuberance PR1 of the inner conductor CI' (B) of branch B which has a length of  $\lambda/4$  and forms the open circuit stub STU1 associated to branch B;
- the inner conductor EP (20) of passing condenser (CP) associated to source D of the DC power enters the glass GHG'H' and is soldered to bottom F of said glass which is integral with a protuberance PR2 connected with inner conductor CI' (B) of the

branch B coaxial line, said second protuberance PR2 being perpendicular to said first protuberance PR1 and forming the inner conductor CI" (B) of short circuited STU2 typically produced by virtue of a third stub STU3 inside the glass GHG'H' and formed by the inner conductor EP (20) of the passing condenser CP and by the inner metallic surface SI of same glass;

- the connection between the STU3 and the bottom of stub STU2 is realized by a coaxial line of which the inner conductor CI" is the outer surface SE of glass GHG'H' and the outer conductor CE" is the extension of outer conductor CE" (B) of stub STU2 plus STU3 which serves to demonstrate that between M (the glass outer vertex) and C (point on the inner surface of conductor CE" (B) facing M) there is a low impedance.

According to a first feature of the invention, stub STU1 is open at the end W-Z. STUB2 is also in series with the line having as internal conductor D-E-G-K-M-P-C and as outer conductor Y-L-S-Q. In this way we succeed in satisfying condition 1, namely to make the STU2 impedance  $Z_{op}$  substantially equal to the STU1 admittance (Yos).

According to an other aspect of the invention, the distance between the free ends facing the two stubs STU2 and STU1 is that between the points N and U and can readily be made the lowest possible, that is it can be kept comprised between  $\lambda/100$  and  $\lambda/10$ . In other words, and with reference to figures 5 and 6, the inner conductor CI (B) of branch (B) shows two protuberances or projections PR1 and PR2; the first protuberance PR1 enters the first cavity CC' (18) within the inner conductor CI (A) of branch A of the coaxial line COAX, and the second projection or protuberance PR2 enters a second cavity CC" (19) formed by the outer conductor CE of coaxial COAX, more precisely by extensions CE' (A) and CE" (B) of branches A and B.

PR1 is  $\lambda/4$  long and is welded to the bottom of the upturned glass BIC.R and forms the inner conductor CI" of the second short circuited stub ST2 that is typically brought about by a third stub STU3 inside the BIC.R glass and is formed by the inner conductor EF (20) of the passing capacity (CP) and of the inner metallic surface (SI) of said glass.

The connection between the third STU3 stub and the STU2 second stub is obtained with a coaxial having, as inner conductor CI", the outer surface SE of the BIC.R glass and as outer conductor CE" the extension of the internal conductor CE" (B) of the second STU2 stub.

A particularly advantageous application of the BIAS-T of figures 7 and 8 according to the invention is that it can have very low dimensions compatible, with miniaturized systems. As an example, in the case of tower mounted amplifiers (TMA) associated to a diplexer and to small dipole antennas it has been possible to integrate the BIAS-T device together with a lightning protector on a printed circuit plate.

While preferred embodiments of the invention have been shown and described herein, it is obvious that numerous omissions, changes and additions may be made in such embodiments without departing from the scope and spirit of the invention.

### Claims

1. A DC polarization device for radio-frequency transmission systems of high power and low intermodulation, comprising a station (A) or source of the RF signal, a station B receiving said RF signal from A on a coaxial line, and source D of direct current DC to be fed to B connected in a knot N to the line AB, the branches AN and DN comprising coaxial elements in short circuit STU2 respectively in open circuit STU1, characterized in that the parallel short circuited stub STU2 has a normalized characteristic impedance ( $Z'_{op}$ ) substantially equal to the normalized characteristic admittance ( $Y_{os}$ ) of the series stub (STU1) and the free heads of the near ends (in knot N) of the two stubs are at the lowest possible distance from each other. 5 10 15 20
2. Polarization device according to claim 1, characterized in that the admittance ( $Y_{os}$ ) has the maximum possible value compatibly with the realization material possibility. 25
3. Polarization device according to claims 1 and 2, characterized in that the distance between the free heads (N, U) of the near ends of the two stubs in the node W is lower than  $\lambda/100$  where  $\lambda$  is the wave length corresponding to the RF signal central frequency (FO). 30 35
4. Polarization device according to claim 3, characterized in that said distance is at most equal to  $\lambda/10$ .
5. Polarization device according to claim 1, characterized in that the inner conductor CI (A) of the coaxial line COAX of the branch A-N has a cylindrical cavity CC' (18) within which protuberance (PR1) of the inner conductor CI' (B) of branch B extends, said protuberance is  $\lambda/4$  long and forms the open circuit stub STU1 of branch A. 40 45
6. Polarization device according to claims 1 to 5, characterized in that the direct current DC source is connected to a passing conductor (CP) the inner conductor (20) of which enters a upturned glass (BIC.R) and welds to the bottom thereof, said glass being integral with a protuberance (PR2) connected to the inner conductor CI' (B) of branch (B) coaxial line, said second protuberance being perpendicular to said first protuberance and forming the inner conductor CI'' of the short circuited stub STU2 brought about in virtue of a third stub STU3 inside to said upturned glass formed by the inner conductor EF 50 55
7. Polarization device according to preceding claims, characterized in that the connection between the first stub STU3 and the bottom of stub STU2 is brought about by a coaxial line of which the inner conductor CI'' is the external surface (SE) of the glass (BIC.R) and the outer conductor (CE'') is the extension of the outer conductor CE' (B) of the second stub STU2.

(20) of the passing condenser (CP) and by the inner metallic surface (SI) of said glass (BIC.R).

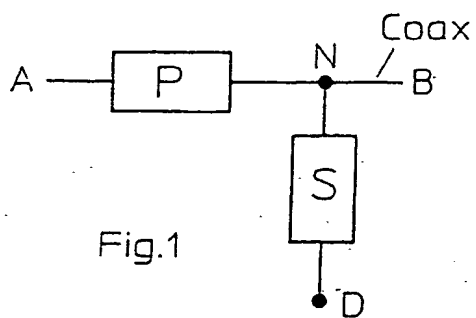


Fig.1

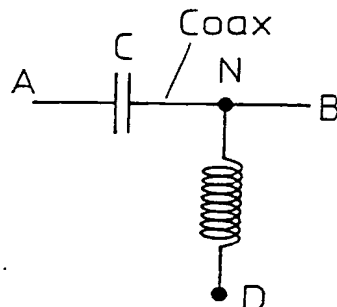


Fig.2

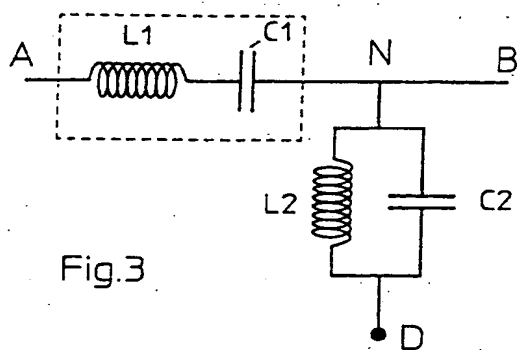


Fig.3

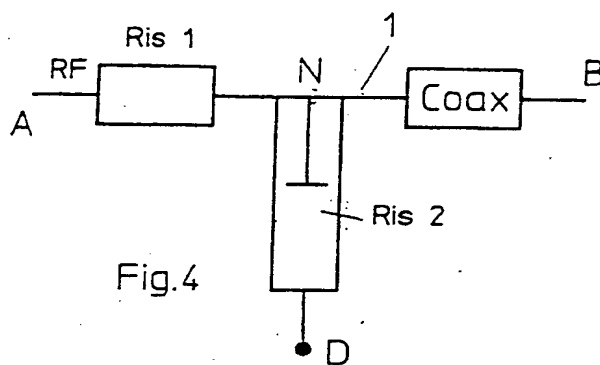


Fig.4

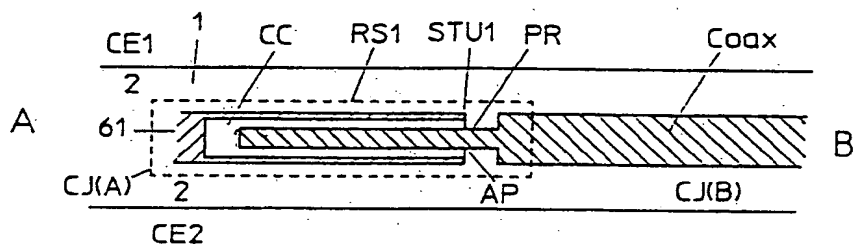


Fig.5

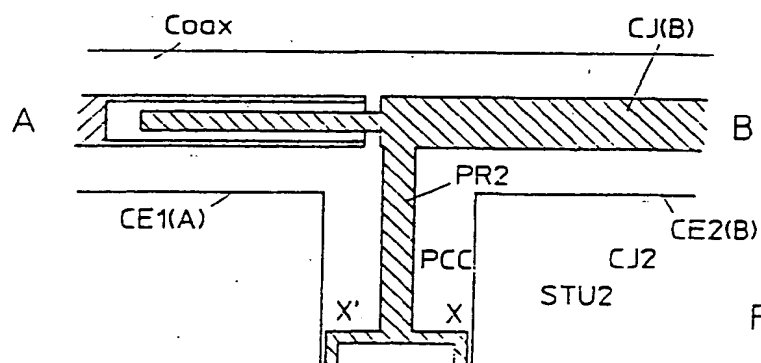


Fig.6

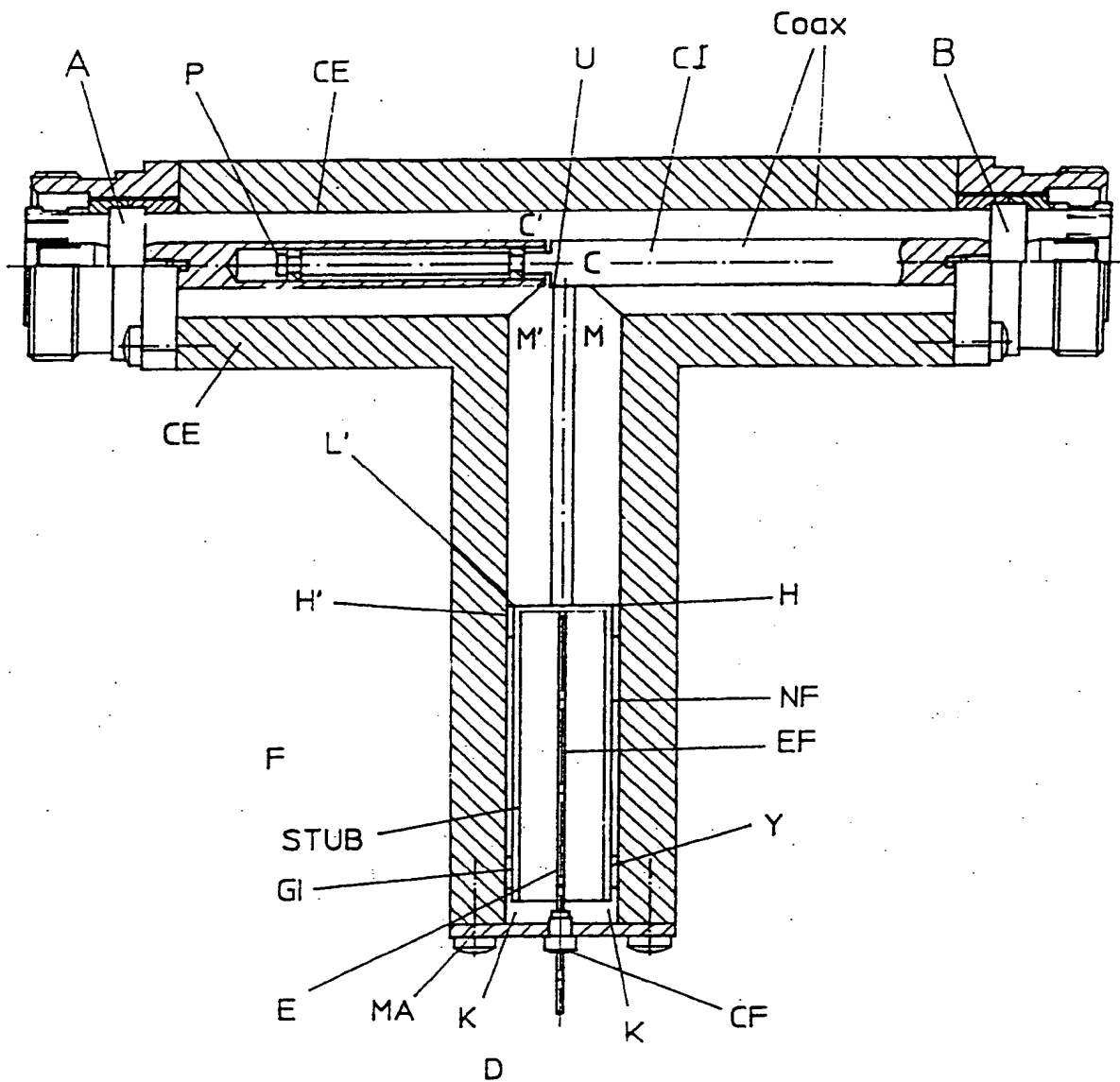


Fig.7

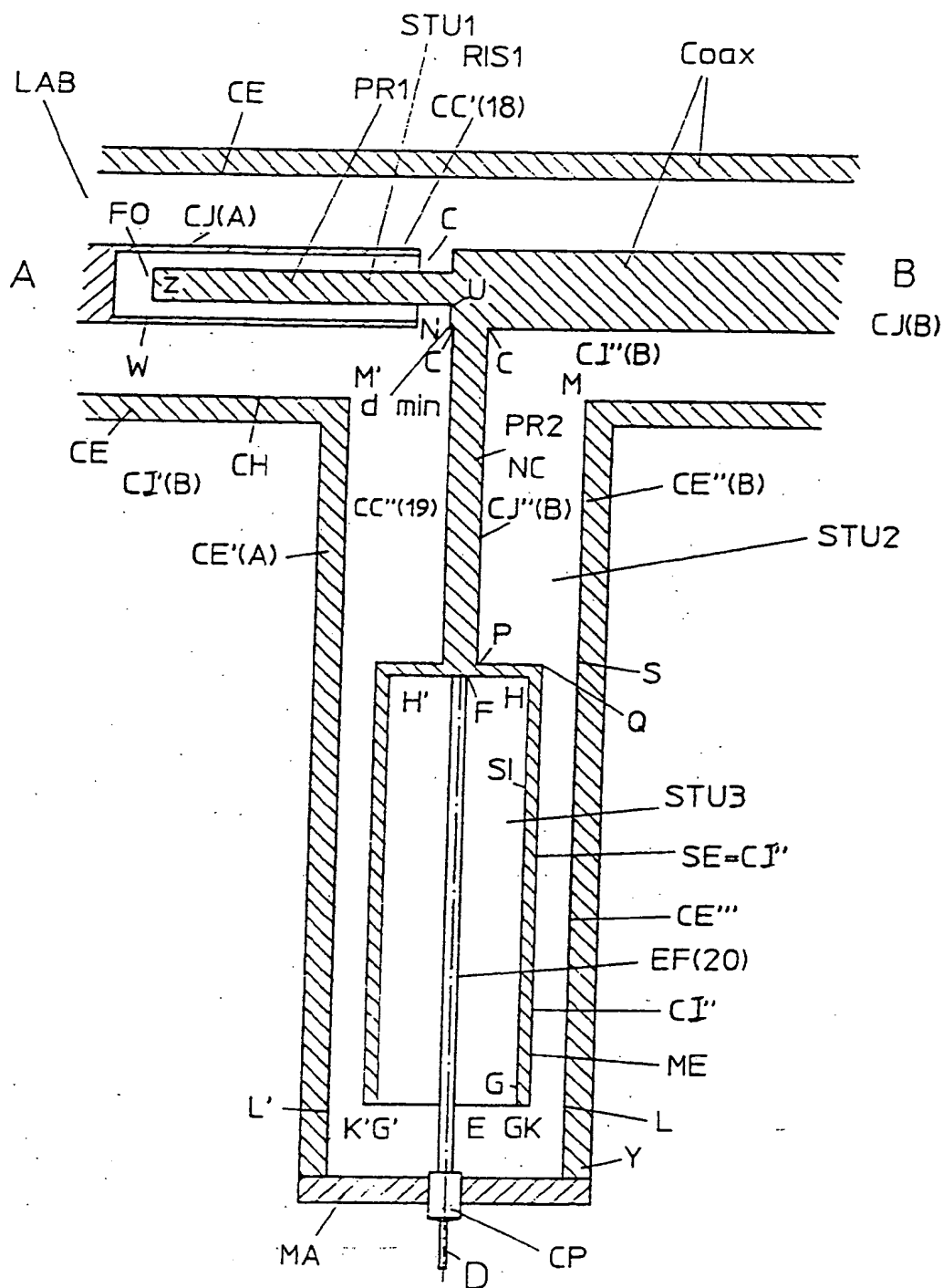


Fig. 8



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# EUROPEAN SEARCH REPORT

Application Number  
EP 96 10 7569

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	CH-A-486 130 (INTERNATIONAL BUSINESS MACHINES CORP.) * column 3, line 34 - column 5, line 22; figures 3,5 *	1	H01P1/20
A	MICROWAVE JOURNAL, vol. 8, no. 2, February 1965, DEDHAM US, pages 33-36, XP002012250 M.M. MCDERMOTT ET AL.: "Very broadband coaxial DC returns derived by microwave filter synthesis" * page 35, left-hand column, line 1 - line 24; figure 4 *	1	
A	FR-A-2 571 550 (SOCIÉTÉ D'ÉTUDES DE TÉLÉINFORMATIQUE ET COMMUNICATION SYSTÈMES) * the whole document *	1	
<div style="text-align: right;">TECHNICAL FIELDS SEARCHED (Int.Cl.6)</div>			
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		2 September 1996	Den Otter, A
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